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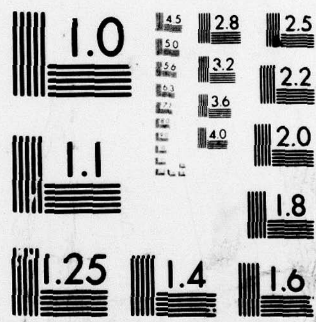

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FORMIROVANIYE KHIMICHESKOY OSNOVY PERVICHNOY PRODUKTIVNOSTI V SEVERNYKH MORYAKH

(Formation of a Chemical Base for Primary Productivity in Northern Seas)

M. V. FEDOSOV

(pages 13-18 in Trudy, VNIRO, vol. XLVI, n. 1, 1962)

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Organic matter in sea water is derived from freshwater run-off from the continents, from atmospheric precipitation, and inert organic matter accumulated in the oceans. Some values are given for production by photosynthesis and content of biogenic elements for areas of the North Atlantic Seas.

Abstract

Sea water bodies are replenished with two types of organic matter, mineral substances and organic material brought into the ocean by continental runoff and precipitation. Most of the newly-formed organic matter is observed during the vegetative period in the photic layer, especially in the narrow coastal belt. When ice forms, drift ice helps to concentrate organic matter in the surface layer. Differences in the origin, concentration, and biochemical use of organic matter affect the type of subsequent links in the food chain: plankton and marine microorganisms.

Two tables show the diurnal production by photosynthesis in mkg-am $O_2|\ell$ by months and the exchange of biogenic elements in various areas of the North Atlantic Ocean, the Barents and Baltic Seas.

Translators Abstract

The original source of organic food formed in sea basins is organic matter derived from phytoplankton. Phytobenthos (plant organisms living in the sea bottom) as representative of primary organic matter has some significance only in bays, the narrow coastal belt, and on shoals where the depth does not exceed 10 to 30-m.

The primary organic nutrients that are formed in the sea by photosynthesis are added to the organic matter brought into seas and oceans from the land. About 0.1 percent of the organic matter in suspension in the ocean is derived from streams. However, land runoff is of substantial significance only in shallow coastal waters and estuaries, notably in bays, and in open areas of oceans and seas is less significant.

The primary organic matter derived from these two sources (as a result of phytoplankton development and stream flow) differ substantially. The qualities that characterize this difference may influence the subsequent initial stages of the food chain in a water body. Studies by a number of investigators, notably B.A. Skopintsev [3, 4], demonstrate that 70 to 80 percent of organic matter formed in a water body consists of compounds that can readily disintegrate, i.e. they are not biochemically stable and can be readily used by marine organisms as nutrients. This means that the organic matter of phytoplankton can, to a degree, serve as a rich nutrient for the small zooplankton and fishes in the photic layer where it is formed. The remaining 20 to 30 percent of the organic matter consists of more stable organic compounds that are not used in large quantities in sea water. Only part of these enter the food chain of organisms, mainly by way of the bacterial flora. B. A. Skopintsev suggested that this portion of organic matter in sea water be called marine humus.

The organic matter washed from the land is a product of soil erosion, plant cover, remains of animals and dead organisms, and detritus washed out of river basins. Up to 70 percent of organic matter derived from stream flow is mineralized while flowing toward the sea, thus forming soil humus and other stable forms of natural detritus. Only 30 percent of organic matter carried by streams reaches seas and oceans in the form of the biochemically stable organic matter that forms a substantial part of the food chain for marine organisms via the bacterial link; part of the material (5 to 10 percent of primary organic matter) sinks (to the bottom) and participates in the marine sedimentation process.

Thus, the further use of the two types of organic compounds, i.e. the food chains, seems to be different. In one case it is the cycle from phytoplankton through zooplankton and ichthyoplankton with the aid of microorganisms; in the other case, when large organic matter circulates with great intensity, it is the cycle through the bacterial link and the zoobenthos. In the first case, the primary organic matter is a source of food formation for small fishes; in the second case, food is formed for larger fishes.

Organic matter derived from land and formed in marine water bodies is a base for subsequent links of the food chain for marine organisms.

Organic substances washed from land and about one quarter of the organic matter of phytoplankton that is formed in the sea and consists of stable biochemical compounds must be used by microorganisms, zoobenthos and other organisms, notably of the filtering kind. If a large quantity of sea water is constantly supplied to the area inhabited by filtering organisms, they can extract enough organic substances from relatively dilute suspensions to satisfy their need for food.

The annual river discharge into seas and oceans totals about 36,000 km^3. The Atlantic Ocean receives about 20,000 km^3 of fluvial and glacial water a year, while the Pacific and Indian Oceans receive 16,000 km^3. Approximately 4,300 km^3 of river water enters the Arctic Ocean through its seas. With respect to the volume of the photic layer (50-m thick) of the entire Arctic Ocean (whose surface area is 13,000 km^2), the influx makes up 0.7 percent; but with respect to the North European basin formed by the Norwegian, Greenland, Barents, and White Seas (surface area - 4,350,000 km^2) the value is less than 0.2 percent because the main discharge of northern rivers enters the central and eastern parts of the Arctic Ocean. In the coastal belt of Scandinavia this percentage abruptly increases.

In the Baltic Sea, where the water is less transparent than in the ocean, the ratio of river discharge to the volume of the photic layer (20-m thick) is about 6.0 percent. Here stream flow plays a substantial role in supplying the water body with nutrients.

A very high rate of photosynthesis in May in Davis Strait [7], which causes the production of organic substances to reach 0.1 to 0.2 mg/ℓ, is observed where the vertical intermixing of water masses is considerable, i.e. in the zone of oceanic fronts, especially in the zone of polar fronts, where water from the Arctic basin meets water of oceanic origin (table 1).

Table 1

Area - Production of photosynthesis per day in mkg-at O_2/ by months

Atlantic water in the Greenland Sea

Arctic water in the Greenland Sea

Southern Norwegian Sea

Central Norwegian Sea

Denmark Strait and Iceland-Tan Mayen region

North of lat. 50° N

South of lat. 50° N

South of Newfoundland

North of Flemish Cap

Davis Strait

Baltic Sea

Район	Продукция фотосинтеза за сутки в *мкг-ат* O_2/л по месяцам							
	III	IV	V	VI	VII	VIII	IX	X
Атлантические воды в Гренландском море	—	—	—	13	—	30	—	—
Ледовые воды в Гренландском море	—	—	—	—	36	47	—	—
Южный район Норвежского моря	0	6	9	—	16	2	—	—
Центральный район Норвежского моря	9	5	9	—	6	—	14	6
Датский пролив и район Исландия—Ян-Майен	0	16	31	0	0	10	26	15
К северу от 50° с. ш.	—	—	—	—	—	51	—	—
К югу от 50° с. ш.	—	—	—	—	—	47	—	—
К югу от о-ва Ньюфаундленд	—	—	—	—	—	2	—	—
К северу от банки Флемиш-Кап	—	—	—	—	—	4	—	—
Девисов пролив	—	—	29	29	—	—	—	—
Балтийское море	—	—	27	27	18	9	—	—

Studies of the formation of water masses [2] and of the fundamentals of primary production [6] in the Arctic front zone showed that special conditions that contribute to an increase in phytoplankton activity exist in a given water body. The special conditions are created in Arctic and oceanic fronts and in areas of drift ice. In places where subarctic water comes in contact with arctic water, the nutrient conditions for plankton organisms improve. Dynamic conditions for the existence of phytoplankton and conditions for diffusional assimilation of biogenic microelements improve when water masses are displaced in vertical or circulatory movements, because the velocity of water movement decreases as a result of division of currents into several branches.

By changing its density [1], phytoplankton can resist the vertical water movement. Because of this, the influx of chemical compounds with steadily changing sea water is intensified, and phytoplankton are supplied with nutrients. Analogous conditions are created in areas of turbulence when the inflowing water motion becomes circulatory and is, to a certain degree, localized in one place. It has been established that in the case of considerable wave motion, when the hydrodynamic conditions that are created in the surface layer are unfavorable to phytoplankton, the maximum photosynthesis is displaced downward to a depth of 25 m where the lighting conditions are satisfactory or at times more favorable and where wave motion is so reduced that phytoplankton can propagate intensively. Large quantities of nitrogenous and organic nutrients are observed in areas where large masses of drift ice concentrate.

Nitrogenous substances concentrate in ice and snow which, being condensations of atmospheric precipitation, are relatively rich in nitrogen compounds, i.e. the products of electromagnetic processes in the atmosphere. Reaching the sea surface in rain, these compounds cannot substantially affect the nitrogen content in northern seas because they make up only fractions of percentages of its stock in the photic layer. Settling together with snow on drift ice, nitrogenous compounds are concentrated, and only when ice masses melt do they reach the photic zone of the upper water layer and briefly, but considerably, enrich the zone with nitrogen and other nutrients. As a rule, the ice, which is subjected to constant wave action, stores organic matter brought by waves until the period of intense ice melting when the substances reenter the photic zone, this time in a concentrated form.

Studies by B. A. Skopintsev [3] established that the quantity of organic matter in sea foam of the coastal belt exceeds many times the amount in sea water. A similar concentration of organic matter takes place in the zone where waves and ice interact. The solid phase of water (ice) accumulates nutrients that are scattered in the ocean water and participate in forming an enriched "chemical base" for photosynthesis in the photic layer of the icy waters of the northern sea areas. The photic layer in Davis Strait and the North European basin of the Arctic Ocean is also supplied by the runoff from glaciers and ice forms on Greenland, Iceland, Spitsbergen and Novaya Zemlya. These are sources of a relatively concentrated simultaneous influx of biologically stimulating substances; however, the quantity of biogenic elements supplied by this source to the photic layer is very small. The processes by which plankton inhabiting the photic zone are supplied with nutrients contained in water substantially affect the formation of primary food in the photic layer of open seas and oceans. However, on the continental shelf, these processes sometimes become secondary to the nutrients supplied the photic layer by stream flow (table 2).

Table 2

Type of Water	Biogenic elements in mkg/ Nitrogen	Phosphorus	Source of data
Atmospheric Sediments	100	___	E. Erickson 1954
Norwegian fjords	___	29	Strom, 1939
Norwegian fjords in anaerobic zones		143	Same
Melting sea ice	Considerable amount	25-70	V. S. Krasnova
Melting snow	390	___	N. Feiltsen, I. Lugner, 1909

The Norwegian Sea is supplied with nutrients that are brought mainly by Atlantic water. However, on the coastal shelf of Scandinavia, continental runoff may be of prime importance in productivity, and in the Barents Sea most of the biogenic elements are supplied by Atlantic water crossing the Norwegian Sea. However, continental runoff is important in the Kolguyev-Pechora and Gusinaya Banka (Goose Bank sectors and on the shoals of Novaya Zemlya.

In the Baltic Sea, river discharge is the principal source of nutrients for the many bays; the sea receives nutrients as a result of water echange with neighboring water bodies and, to a considerable degree, with inflowing North Sea water.

However, because North Sea water is more dense than Baltic water, North Sea water collects in the bottom layer of the principal depressions of the Baltic Sea. Consequently, the biogenic elements entering the Baltic Sea in this way penetrate the photic layer on a very limited scale, and only where upwelling of bottom water occurs.

In the Gulf of Riga, the ratio of river discharge to the water mass is 7 percent, but the ratio to the water covering shallow areas is considerably greater: in Parnu Laht (Zaliv Pyarnu) the ratio is 40 percent, in Frisches Haff (Vislinskiy Zaliv) 70 percent. The upwelling of bottom water in the Gulf of Riga and the Parnu Laht is of interest. In this case, the stock of nutrients that accumulates in the relatively large water body is concentrated in the photic layer whose volume is much smaller, but whose productivity is very great. The Kurishches Haff (Kurskiy Zaliv) of the Baltic Sea (the estuary of the Nemanas River) is mainly a fresh water body; the volume of river water passing through the gulf is more than twice the volume of the gulf. Only in a small northeastern section is the effect of Baltic Sea water noticeable. This makes it possible to compare the habitat and development of commercial species of marine organisms in a given water basin.

The results of studying conditions and cycles in the formation of the chemical base of primary production in seas and oceans are valuable in appraising primary production and primary production in marine water bodies and constitute a base for improving the water regime in order to increase the commercial value of water bodies.

Conclusions

1. Sea water is replenished with two genetically different types of organic matter. Organic matter synthesized by phytoplankton in the photic layer (the components of the synthesis are mineral substances) and organic matter from land washed into ocean by the continental runoff and atmospheric precipitation on sea surface.

2. Large amounts of "old"organic matter, which are tens and hundreds of times the annual inflow of new organic matter, have accumulated in the sea. However, this accumulated organic matter is biochemically very inert and can be assimilated only by a limited number of marine organisms. Both types of organic matter are used as the initial link of the trophic chain of heterotrophic marine organisms. In the subsequent food chain the organic matter is more intensively used when the concentration is at a maximum.

3. A greater concentration of newly-formed organic matter is observed in the photic layer of various regions of northern seas during the vegetation period. Continental runoff supplements the concentration of organic matter in the coastal belt of seas and gulfs. When ice is formed in northern seas, drift ice increases the concentration of organic matter received by atmospheric precipitation in the surface water layer. When the ice melts, a large quantity of organic matter accumulates in the surface water layer.

4. Differences in the origin, the degree of concentration, and the biochemical use of both types of organic matter in seas must also affect the character of the subsequent biological links in the food chain; plankton, benthic organisms, or marine microbes.

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